



Applying Digital Twins to the Built Environment

**A DIGITAL TWIN IS A CONNECTED, VIRTUAL REPLICA
OF A PHYSICAL PRODUCT, ASSET, OR SYSTEM.**

Digital twins turn the physical world into computable objects. Computable objects provide a consistent way for software to manage and represent entities from the physical world. Digital twins can be used to represent the past and present state of physical objects, to predict the future state of physical objects, and to simulate or test future processes and changes to answer “what-if” questions.

Digital twins provide a way to combine a number of techniques, such as streaming sensor data, analytics and machine learning, and enabling knowledge graph representations of the world, creating a developer-friendly interface that bridges the digital and the physical world. Although most of the techniques already existed as stand-alone capabilities, digital twins provide a common framework to bring them together and more rapidly innovate.

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Improving Building Systems with a Digital Twin

One common application of a digital twin is modeling building systems. The twin uses information technology and operational technology, such as construction data and floor plans for the building, real-time sensor data from the building management system, data from HVAC systems, lighting, fire, security, and other environmental sensors, as well as data about the assets of the building and the people who use it, such as tenants, occupants, building staff, visitors, and other roles.

BEFORE/DURING CONSTRUCTION

A building twin can identify & improve:

- System interactions and integrations
- Installation obstacles
- Selection of providers
- Cost and maintenance predictions
- Construction risks

AFTER CONSTRUCTION

A building twin can predict:

- Security incidents
- Parts replacement schedules
- System inefficiencies
- Process integration impacts

BUILDING A DIGITAL TWIN

All buildings have a lifecycle. It starts with the spark of an idea by a developer or other visionary about how to transform an existing building or to create something new. The lifecycle starts there and brings in the architects for the conceptual and engineering design phase and then moves into construction, commissioning, and then hopefully, a long, many-year stretch of operations and minor remodels to the building, until finally someone else comes along with a new spark of an idea and embarks on a major remodel or demolition of an existing building and starts the cycle over.

It is clear that having a digital twin – and the same digital twin – for all steps of the building lifecycle unlocks some powerful capabilities. Historically, there have been digital representations of a building, but typically, each phase of the building lifecycle ignored the digital representation from the previous phase so the data from the design phase was not used in the commissioning phase, and the commissioning data was not kept up-to-date in the operations phase. This meant that none of the digital representations of the building were ever truly complete or up-to-date and hence were never as powerful as an ideal digital twin could be.

Preferably, the digital twin is born first, before its physical counterpart. Long before construction begins, the architect creates the first version, and unlike the paper drawings of years past, the digital design can immediately become a living thing, standing in for the physical building in simulations. As the drawings and plans change, the digital twin in turn updates and recomputes itself. It can evaluate physical characteristics innate to the building itself, such as modeling airflow or energy usage, or it can evaluate the building in a larger environment, such as predicting the effect of the building on the traffic flow of the neighborhood. The digital twin may go through thousands of changes and millions of simulations before it is eventually used to guide the construction of its physical sibling.

In other cases, especially for existing buildings, the digital twin is born well after the physical version was created and placed into use. In this ordering, the first version of the digital twin stands as a very coarse approximation of the physical twin, and over time, as more data is measured or acquired and additional real-time sensors are integrated, the digital and physical versions become more alike in detail and fidelity.

Digital twins differ from Building Information Modeling (BIM) in that BIM is a *process* and digital twins are real-time virtual representations. BIM involves the generation and management of digital reproductions of physical and functional characteristics of places, whereas digital twins can serve as repositories of BIM data as well as a much broader array of building automation systems and sensor networks.

Data Collection for Digital Twins

The data collected for digital twins can come from a variety of sources. A true digital twin must be a "system of systems" integration:

- **Embedded sensors:** Used to create digital twins of individual equipment (e.g., an HVAC unit) or a larger system. Embedded sensors transmit operational data from equipment to operators who monitor the system and control it remotely. Equipment categorized as "smart" would allow for this.
- **Wireless sensor networks:** Installed in buildings to collect data on temperature, humidity, lighting, occupancy, and other factors. Wireless sensors have the advantages of easier system expansion, flexibility to relocate sensors as space needs change, and more seamless installation.
- **Digitized building lifecycle data and systems:** BIM data, connected and smart HVAC systems, digitized pneumatic thermostats, smart plugs, and smart elevator controls are all opportunities to channel data and build a digital twin.
- **Integration with other cloud services and data providers:** Data may be integrated into the digital twin from outside sources, such as weather data or from 3rd party "cloud to cloud" integrations. In cases where systems do not communicate directly with the local sensor network but instead connect to a 3rd party vendor's cloud, the building must pull data from that vendor's cloud.

APPLICATIONS FOR DIGITAL TWINS IN THE BUILT ENVIRONMENT



Prediction

The digital twin brings together all of the data necessary for predictive algorithms and artificial intelligence systems, from fault predictions on equipment to building utilization and optimization.



Operations

A digital twin of a building gives building managers and occupants a real-time view of the integrated systems of the building. This is a powerful construct that can be used for everything from top-line dashboards of building health to specific applications like asset and people tracking, hot desking, integration with transit and parking, and building operations based on conditions rather than fixed schedules.



Cost Reduction

Digital twins help buildings operate more efficiently by helping predict and avoid unexpected costs, identify system inefficiencies, and better estimate when replacement parts are needed.



Risk Mitigation

Running simulations on a digital twin reduces risks and helps system engineers make better business cases for changes to the system. Experimenting on the digital twin also can help mitigate equipment downtime.



Understanding System Interactions

Digital twins from multiple systems and objects can be combined to better understand how they will interact with each other. This is particularly helpful when systems and products come from different suppliers.



Security

The digital twin provides a real-time view of the building and its occupants while incorporating historic trend data. The digital twin can be used to highlight "abnormal" actions or events that could portend security issues.

CONCERNS ABOUT DIGITAL TWINS

1 LACK OF DATA STANDARDS

Standards would help companies make smart technology development investments.



Johnson Controls is a founding member of the Brick schema consortium that is working to standardize a unified approach to building representation.

Visit www.brickschema.org for more information.

2 CYBERSECURITY

Cyber intruders could potentially use a digital twin to gain access to confidential building information.

3 TECH OVERKILL

Digital twins aren't always called for and can unnecessarily increase complexity.

4 CHANGE MANAGEMENT

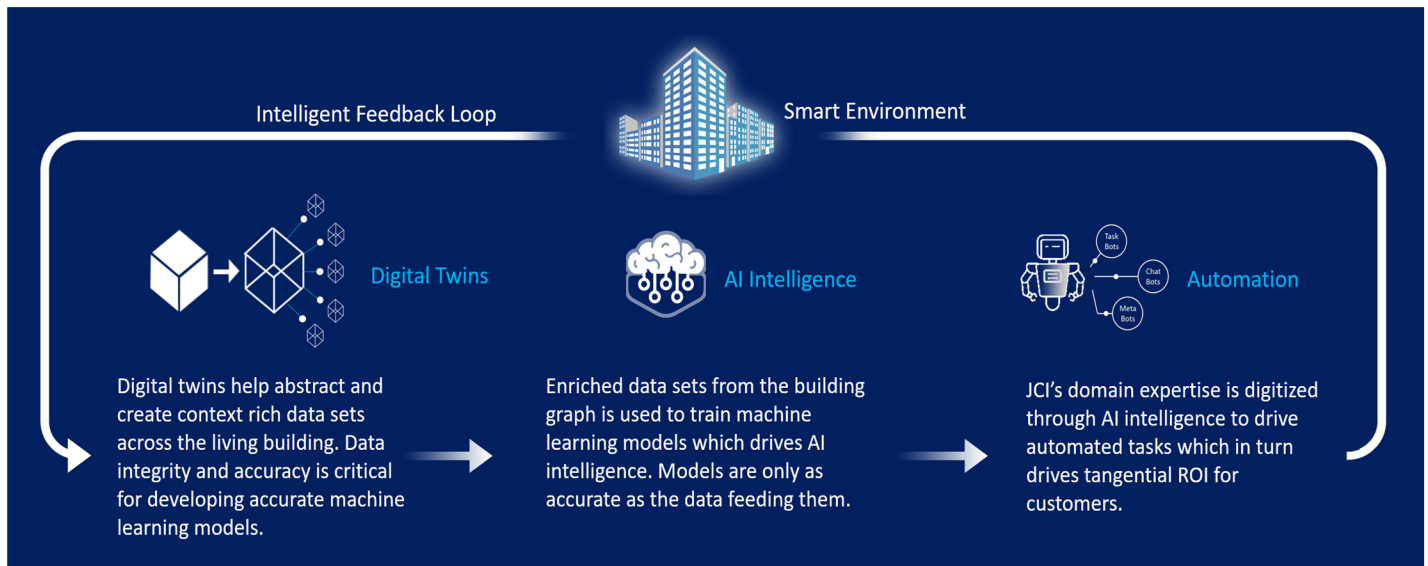
The digital twin is only as good as its input data. Enterprises have struggled to find value in their BIM practices because the BIM is rarely kept up-to-date. A digital twin of the building will also need to be kept up-to-date, but it is possible to use the digital twin of the building to help make the tools to keep the digital twin updated.

THE IMPACT OF DIGITAL TWINS

IDC research outlines a Digital Twin Maturity Model that begins with Digital Visualization and moves through Digital Development, Digital Enterprise, Digital Ecosystem, and finally Digital Twin Orchestration¹. Digital twin technologies can have a positive impact on building management and operations across the entire value chain, moving from ideation and visualization of processes to service and management at a greater and greater scale. A mature digital twin allows for decision support and real-time visibility of products, assets, facilities, and manufacturing.

¹ reference IDC: Apr 2018 – IDC PlanScape – Doc # US43134418 IDC PlanScape: Digital Twins for Products, Assets, and Ecosystems

JOHNSON CONTROLS OPENBLUE TWIN



OPENBLUE PLATFORM ENABLES AND ENHANCES THE DEVELOPMENT OF A DIGITAL TWIN. THIS ALLOWS FOR INCREASED PRODUCTIVITY, IMPROVED OCCUPANT AND BUILDING HEALTH, OPTIMIZED ENERGY EFFICIENCY, AND OVERALL DATA SHARING ACROSS APPLICATIONS FOR BETTER OUTCOMES.



For Assets

OpenBlue Bridge collects real-time edge IoT data from different equipment manufacturers and sends it to OpenBlue Cloud and OpenBlue Twin for processing. The asset metadata and building configuration data is also stored in the building knowledge graph. OpenBlue Platform recognizes the asset and event types allowing analytics and predictive modelling. OpenBlue Twin provides a secure and structured way to enrich asset data sets for insightful data sharing across both Johnson Control applications and third-party applications.



For Places

Places and spaces within the built environment represent where assets, people, and events take place. Digitally captured asset meta data is replicated in the digital twin for the purpose of data preparation and situational simulation. When the physical environment changes, the digital twin is updated to reflect an exact replica of the as-built environment.



For People

Data is obtained from enterprise people systems, office productivity software, access control systems, etc, can be captured in OpenBlue to create digital twin relationships between people, spaces, assets, and system events.



Applications

OpenBlue Twin provides additional context to make the digital twin more effective. It models not only devices but the entire built environment and enterprise around the device, so the digital twin can make informed decisions and respond to the user requests. For example, the digital twin for a VAV box knows how to find the digital twin for the air handler that feeds it, so the analytics on the VAV box can automatically run algorithms using current and historic data for the AHU. Another example - a digital twin for a parking ramp knows how to communicate with the digital twin for the security system. So when an employee or visitor's car is detected in the parking garage, the building can start adapting for the person's arrival.



Brick

Data Model

One of the biggest challenges facing the global building industry today is the lack of a common data model for the applications and systems that exist within buildings. This prevents interoperability and limits scalability, issues that costs the industry and estimated \$15 billion annually². Brick is an open-source development effort designed to address the challenges by creating a uniform schema for representing metadata in buildings. Brick is flexible and expressive, enabling the next generation of building environments. Johnson Controls is a founding corporate sponsor of the Brick consortium, a group that will drive the development and adoption of Brick.

Visit www.brickschema.org for more information.



Find other industry education and insights at
www.johnsoncontrols.com/insights

² reference IDC: Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry, National Institute of Standards and Technology, retrieved 4-19-2018 from <https://nvlpubs.nist.gov/nistpubs/gcr/2004/NIST.GCR.04-867.pdf>